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ABSTRACT

Investments in technology and the number of workers using computers are growing quickly and at an increasing rate. From 1990-1995, investments in computers and related equipment tripled. Real (inflation-adjusted dollars) investments in computers and peripheral equipment increased from $200 million in 1973 to $91.6 billion in 1995. Increasing investments in computer equipment have not yet resulted in increased productivity growth, however; growth in productivity is actually slowing. Some explanations for this paradox include the following: (1) investments in technology require investments in worker training before increased productivity is noted; (2) investments in technology are seen as ways to improve quality but not necessarily quantity; (3) computers represent only a small portion of the total stock of capital in the U.S. economy, so increasing them has little effect on overall productivity; (4) problems in measuring productivity may underestimate the contribution of computer investments to productivity improvements, especially in the service sector where they are most prominent; and (5) productivity slumps as new technology is assimilated but may surge again afterwards, as it has after all earlier innovative periods. In addition, although productivity gains as part of the whole economy are small and difficult to measure, individual companies provide examples of great gains in productivity through use of technology. Increased training will increase workers' skills in using computers and lead to more high-level jobs and an eventual growth in productivity. (KC)

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WORKFORCE ECONOMICS

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WAITING FOR THE RETURN
MAXIMIZING INVESTMENTS IN TECHNOLOGY

Businesses have been preparing for the information age since the early 1970s, when they first began investing in computer technology. Today, as we move closer to an economy in which the flow of information provides a critical competitive edge, businesses are putting more and more capital into technology. Despite the explosion in investment, however, neither productivity nor economic growth shows significant improvement at this time. Moreover, how information technology is changing work — and what skill sets are necessary to function in the labor market — are unclear.

> "It is no longer the production of technology, but its application, that creates growth opportunities."
>
> – David Birch, president, Cognetics, Inc.

Some are painting technology, the computer in particular, as a villain that destroys jobs and increases wage inequality (see *Workforce Economics*, April 1996). While technology may result in some displacement in the short run, new and expanded employment opportunities will be created in the long run.

It is logical that the technological revolution is raising such questions. After all, "Technology changes the organization in all ways ... it alters the structure, it changes the values embodied in the organization, and it creates new skills," Richard Measelle, worldwide managing partner, Arthur Andersen, noted at a 1996 World Economic Forum. Technology also is changing education and training — both in the classroom and in the workplace (see *WorkAmerica*, December 1996).

How we use technology ultimately will determine whether today's investments are wise. As David Birch observes, "It is no longer the production of technology, but its application, that creates growth opportunities ... rapidly growing companies ... are applying technology and knowledge-value to revolutionize their industry." History proves him right. The advent of computers isn't the first major change to affect business and industry. The industrial revolution and the introduction of electricity initially depressed labor productivity. The lag time between the introduction and initial investment in new technology and productivity growth was between 30 and 40 years.

Today, 46 percent of U.S. workers use computers on the job, and this number is expected to grow. By the early part of the next century, we expect that three-quarters of the labor force will use technology on the job. Some businesses, industries and workers already are benefiting from this transition. If aggregate productivity is to increase, businesses must ensure that their employees understand and effectively use new technology. Investments in training will become critical to ensure that the investment in technology translates into faster rates of productivity growth.

Investments in Technology Explode ...

Investment in technology and the number of workers using computers are growing quickly — and at an increasing rate. From 1990 to 1995, investments in computers and related equipment tripled. Real (inflation-adjusted dollars) investments in computers and peripheral equipment increased from $200 million in 1973 to $91.6 billion in 1995. The rate of growth continues to climb: During the first two quarters of 1996 alone, computer and peripheral equipment investments averaged nearly $122 billion. (See chart, page 4.)

In 1984, one-quarter of all workers used a computer on the job. By 1993, only nine years later, that figure had almost doubled (46 percent). There also is a strong correlation between education and computer use on the job. When compared with workers who are high school dropouts, high school graduates are more than three times as likely — and college graduates are nearly seven times as likely — to use computers on the job. (See chart, page 5.)

... But Productivity Growth Slows

Increasing investments in computer and peripheral equipment have not, as yet, resulted in increased produc-

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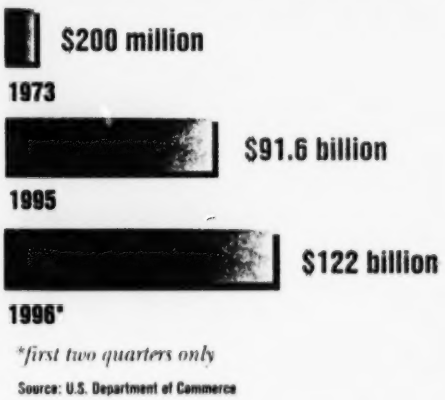
Investment in Technology Shoots Up

In real dollars ...

Investments in computers and related equipment increased from $200 million in 1973 to $91.6 billion in 1995 (inflation-adjusted dollars). But investments for the first two quarters of 1996 eclipse 1995 total spending.

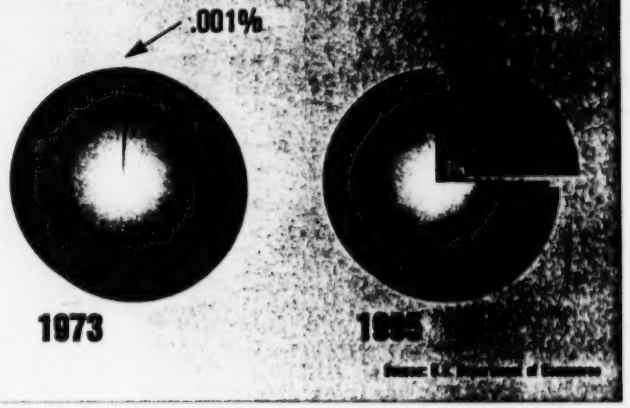


**first two quarters only*

Source: U.S. Department of Commerce

... and as a percentage of prod durable equipment

From 1973 to 1995 businesses' investm and related equipment also grew as a per all investment in producer durable equ than one-tenth of one percent to almost investment in all producer durable equ



tivity growth. In fact, just as investments in technology exploded, productivity growth *slowed*.

The rate of productivity growth in the business sector began to decline around 1973 for a variety of reasons. (Productivity grew at a 2.9 percent annual rate from 1959 to 1973, and at a 1.2 percent annual rate from 1973 to 1995.) More importantly, while computer investments tripled from 1990 to 1995, productivity grew at only a 1 percent annual rate during that time. (See chart, page 6.)

Economists have been puzzled by this fact for several years. As Robert Solow wrote in a 1987 *New York Times Book Review*, "You can see the computer age everywhere except in the productivity statistics."

Explaining the Paradox

Martin Baily and Robert Gordon in a 1987 Brookings Institution study found a weak association between productivity and computer investments. They speculate that investments in technology may not show returns because workers require retraining and companies must learn how to incorporate new technologies efficiently. For many manufacturing establishments, however, technology is seen as a way to improve product quality and productivity. A 1993 Census Bureau study found that 86 percent of establishments surveyed were using technology to improve product quality and improve productivity. Only 5 percent reported using technology as a way to lower labor costs.

Several researchers have examined this paradox and offered three potential explanations. First, computers represent only a small portion of the total stock of capital in the U.S. economy. For investments in computer equipment to have an appreciable effect on aggregate productivity, they would have to have an overwhelming impact on computer-related labor productivity; because computers represent a small (at this time) portion of capital stock, their impact on overall productivity is dampened. Lichtenberg, in a 1993 National Bureau of Economic Research (NBER) study, found that of the more than 200 companies for which he had data, computer capital represented only about 2 percent of the companies' total capital stock.

Second, problems in measuring productivity may underestimate the contribution of computer investments to productivity improvements. For example, computer investments are highly concentrated in the service sector, particularly in industries such as health care and financial services. These are the industry sectors where it is most difficult to measure productivity.

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Finally, some researchers suggest that the economy is on the verge of a surge in productivity growth because of these investments. Paul David of Stanford University and Jeremy Greenwood of the University of Rochester in separate studies argue that we should expect a delay before technological improvements deliver significant gains in productivity growth. Both researchers explored the effects of new technologies, the advent of electricity, and the industrial revolutions in Britain and the United States. They found that productivity growth slowed at first as both workers and companies learned to use the new technology. The similarities between these earlier "revolutions" and the current situation are compelling. History shows that new technologies create a predictable cycle as they are diffused through the economy:

- Productivity slumps as the new technology is introduced and then surges once the new technology is diffused through the economy.
- The premium for skills increases rapidly as more educated and skilled workers have a competitive advantage in using the new technology.
- Wage inequality increases as a result of the introduction of the new technology, but then levels off once the technology is diffused throughout the economy.

Individual Companies, Industries, Reap Benefits More Quickly

Although the effect of computers on economy-wide measures of productivity is mixed, a different picture emerges with a more narrow focus on individual firms and industries.

Many companies are using technology effectively to gain a competitive advantage and improve productivity within their company. For example:

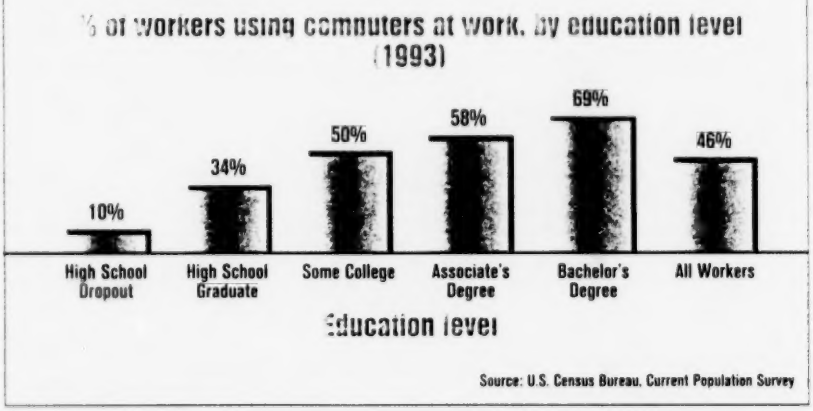
- Wal-Mart is using computer technology to provide sales information from each store's checkout counters directly to suppliers. In the extremely competitive retail trade industry, this immediate, store-specific information provides Wal-Mart a critical edge.
- UPS and Federal Express are using information technology to send information to customs services so that shipments can be cleared before arriving.
- Kodak used computer-aided engineering tools to reduce the design and development cycle for its single-use 35mm camera. Chrysler, Ford and GM are doing the same in the auto industry.
- Johnson & Johnson is using technology to help company executives track the progress of drugs through the research and development cycle.

On the industry side, a 1987 study by Mark published in the *Monthly Labor Review* found that more investment pays off. Industries that made the largest investments in new technology experienced productivity growth five times higher than that of the economy as a whole.

Lichtenberg, in a 1993 NBER study, found that investments in computer technology generated excess returns when compared to investments in other capital goods. He estimates that the return on investment (ROI) for computers was between 2.5 and 3.5 times higher than the ROI for other capital. Related work by Brynjolfsson and Hitt of MIT found that the ROI for information systems averaged 54 percent for manufacturing firms and 68 percent for companies in both manufacturing and non-manufacturing sectors.

More Educated Workers Use Computers on the Job

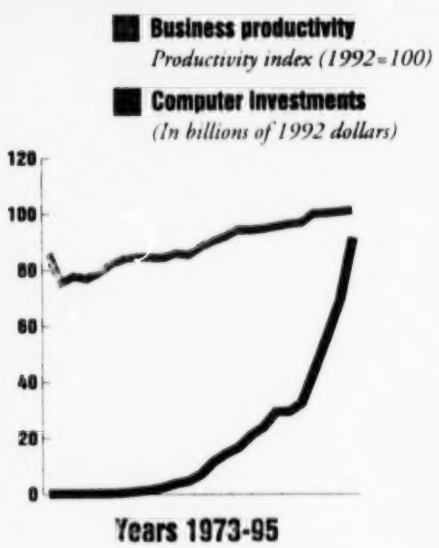
There is a strong correlation between education and computer use on the job. A recent National Bureau of Economic Research study by David Card and colleagues showed that rates of computer use at work in the U.S., Canada and France are similar.



Source: U.S. Census Bureau, Current Population Survey

Productivity Growth Lags Behind

Investments in technology exploded in the 1980s but have not yet led to faster productivity growth.



Source: U.S. Department of Commerce, U.S. Bureau of Labor Statistics

Investments in Training Become Essential

Training, however, is critical to the successful implementation of technology. As technology investments increase, skills training will become more important. Sandra Black and Lisa Lynch recently found that doubling the percentage of workers using computers raises labor productivity in the manufacturing sector by 5.4 percent. In the non-manufacturing sector, however, Black and Lynch found that computer-skills training has a significant, positive effect on productivity (1996 study published in the *American Economic Review*.)

This finding is due in part to the fact that computers are more prevalent in the non-manufacturing sector, where nearly 90 percent of computer investments are made. Because manufacturing firms are less intensive users of technology, increasing the use of technology will increase productivity. In the non-manufacturing sector, however, training workers to better use technology already in the workplace is likely to have a higher payoff.

The manufacturing sector may have invested less, but recent surveys by the Census Bureau show how rapidly the manufacturing sector is incorporating new uses for technology. From 1988 to 1993, the number of manufacturing establishments using technology to design and engineer products increased by 57 percent, the number of manufacturing establishments using technology to assemble products rose by 21 percent and the number of manufacturing establishments using technology to communicate and control the production process increased by 25 percent.

Workers Earn More by Using Technology

Workers using technology on the job are more productive and are paid more. A study by Alan Kreuger published in the *Quarterly Journal of Economics* in 1993 found that workers who use computers on the job are paid about 10 percent to 15 percent more than similar workers who do not use computers on the job. Peter Cappelli recently found that workers who use computers are paid more than workers who don't use them.

Dunne and Schmitz found that production workers in plants using technology more intensively in their jobs earned 14 percent higher wages than production workers in plants using the technology less intensively. Doms and his colleagues at the Center for Economic Studies found that when worker quality characteristics (education level, for example) are constant, production workers using more advanced production technology earn 8 percent to 9 percent more than workers using less advanced production technology.

Finally, a 1996 study by Steven Allen for NBER finds that workers in industries with high penetration of computers have higher returns to schooling than workers in industries with lower penetration of computers. Moreover, he finds that the use of computers and other high technology accounts for about one-third of the increasing wage gap between high school and college graduates. Allen also found that computers and high-tech capital narrowed the wage gap between male and female workers (see the September 1996 issue of *Workforce Economics*).

Computers Affect Both Work And Skills

In his book *The End of Work*, Jeremy Rifkin suggests that technology is quickly replacing the need for human beings. A study examining the relationship between technology, productivity and job creation by the Organisation for Economic Cooperation and Development (OECD), however, shows otherwise.

The report shows that although technology does destroy some jobs, this loss is offset by gains in productivity and new products associated with the new technology — which lead to economic growth that ultimately creates more jobs than were initially destroyed. This process of creative destruction, fueled by technology, provides the engine of U.S. economic growth. Other studies support the findings that technology's impact on employment is positive, and that technology up-skills rather de-skills jobs, creates new jobs, and generates demand for new skills and occupations.

Since 1979, when investments in computer and related equipment

took off, employment on non-farm payrolls grew by 27.4 million jobs through the end of 1995. In the 16 years before 1979, employment grew by 33.2 million jobs. Data reported by OECD also highlights how employment growth is concentrated in economic sectors demanding more educated and skilled workers. These aggregate figures and other research begin to flesh out the picture of the relationship between technology and employment. For instance, a recent study by Card and his colleagues for the NBER found a positive relationship between the use of computers, employment growth and wage growth for more educated groups in the United States, Canada and France.

The same trend seems to hold true internationally. In *Technology, Productivity, and Job Creation*, OECD found a positive relationship between investments in information technology and employment growth in "market services," including finance, insurance and real estate, wholesale and retail trade, transportation, communications, and business services. Those countries and industries that made the greatest investment in information technology experienced the greatest gains in employment. (See chart, this page) Moreover, they found that employment in the manufacturing sector across the G-7 countries is growing in high technology manufacturing industries and declining in low technology manufacturing industries.

At the same time, technology has shifted labor demand. Peter Cappelli, in a study published in the *New England Economic Review*, found that U.S. businesses that invest in technology up-skill rather than de-skill jobs. Doms, Dunne and Troske find a positive relationship between technology investments and employment of more educated production and non-production workers in manufacturing firms. They found that the proportion of production workers with some college education was 1.5 times higher in establishments making more intensive use of technology than it was in those making less intensive use of technology.

In a 1994 study in the *Quarterly Journal of Economics*, Berman, Bound and Griliches found that when manufacturing industries increased their investments in computer technology, demand shifted from unskilled to more skilled labor. Cappelli, in a 1993 study, also found that skill requirements in manufacturing jobs were higher as a result of technology. Mixed effects were observed for clerical jobs.

A survey by the Olsten Corporation found that the need for computer literacy among managers and other professionals rose by 35 percent between 1990 and 1993. Now, more than 70 percent of management positions require computer skills.

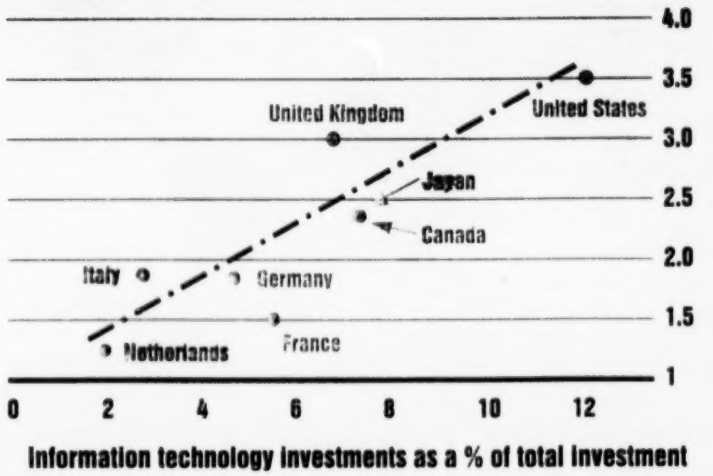
Implications

Technology is an important factor in helping understand how and why jobs are changing. Technology and skills are complements. As technology increases, the skills demanded in the workplace increase. As computers become more prevalent, we must ensure that students have access to them throughout their school careers — from K-16.

Technology is creating jobs, and in many sectors, it also is increasing demand for more skilled, more educated workers. The basic skills needed in the workplace are increasing. Moreover, as new technologies are introduced with increasing speed, the importance of ongoing training will continue to grow. Not only will the need for technical skills training increase, but training in other skills will increase as well.

Technology is not, however, a cure-all for business ills. Technology without training wastes scarce investment resources. As Robert Stempel, former CEO of General Motors, observed, "We tried automation without knowledgeable workers, and it doesn't work."

Information Technology Investment and Employment Growth in Market Services



Source: OECD, *Technology, Productivity, and Job Creation*, Vol. 2.

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